The Impact of Microorganisms of Circulating Water on Apatite-containing Ores Flotation and Conservation of Tailings

G.A. Evdokimova[1], A.Sh. Gershenkop[2] and N.V. Fokina[1]

[1]Institute of the North Industrial Ecology Problems of Kola Science Centre RAS, Apatity, Russia

[2]Mining Institute of Kola Science Centre RAS, Apatity, Russia

galina@inep.ksc.ru; alex@goi.kolasc.net.ru; voronina@inep.ksc.ru

Abstract

A new phenomenon has been identified and studied – the impact of bacteria on the benefication process of non-sulphide ores using circulating water supply - a case study of apatite-nepheline ore. It is shown that bacteria deteriorate the floatability of apatite due to their interaction with active centres of calcium-containing minerals and intense flocculation, resulting in a decrease of the flotation process selectivity thus deteriorating the quality of concentrate. The dominating bacteria in circulating water are related to γ-Proteobacteria including *Acinetobacter* sp., *Pseudomonas alcaliphila*, *Ps.plecoglossicida*, *Stenotrophomonas rhizophila.* A method of non-sulphide ores flotation has been developed with consideration of the bacterial factor. It consists in use of small concentrations of sodium hypochlorite, which inhibits the development of bacteria in the flotation of apatite-nepheline ores. Bacteria and fungi producing acids and polysaccharidic mucus into environment carry out biogenous destruction of minerals. This process takes place during industrial waste conservation in tailing impoundments where loss of commercial elements and potential environment contamination can occur.

Keywords

Apatite-Nepheline Ore; Circulating Waters; Bacteria; Flotation; Mineral Destruction

Introduction

In Murmansk region of the Russian Federation apatite - bearing ores of Khibiny and Kovdor deposits are produced being the basis for phosphorous-containing products such as fertilizers and phosphorous acids.

The ore processing technology is based on flotation method which allows obtaining high quality concentrates. The flotation be done circulating water supply which is an important step in the environment protection. However, the use of circulating water caused a significant increase in the consumption of reagents used in flotation. The reason of this is the increase in the circulating water of fine-dispersed phase, residual concentrations of reagents and products which are part of the composition of fatty acid collectors. All these compounds favour the increase of bacteria number in the circulating water. Microorganisms of circulating water can influence the flotation process by changing surface state of floating minerals. The role of bacteria can be played in the two-ways: promoting the flotation process and inhibiting it. Bacteria cells and their metabolites can be absorbed by the surface of minerals, having impact on its surface, changing it thus resulting in change of flotation properties. It is evident that microorganisms can transform minerals in the tailings of concentration plants and have impact on its conservation. Tailings being long-term in liquid phase of the tailing impoundment can contribute to it.

The goal of this work is to study the impact of microorganisms of circulating water from concentration plants dealing with apatite-bearing ores processing on flotation properties of calcium-containing minerals and its conservation under tailing impoundment conditions that can be considered technogenic deposits.

Material and Methods

Samples under Study

Studying the processes of bacteria impact on the benefication of apatite-nepheline ores was taking place directly at concentration plants in a continuous cycle of its processing, and surface transformation was considered on mineral samples as apatite, nepheline as a second important in apatite-nepheline ore composition and cyanite for comparative studies.

A microbiologocal study has been carried out at all stages of the process of apatite-nepheline ore benefication. Samples of circulating water, ground ore, mill overflow, froth product, thickener's overflow of apatite cycle, filtrate, concentrate after drying, collective mixture and flotation reagents have been analyzed. To identify the microorganisms' number, samples were taken in all seasons of the year.

Microbiological Analysis

The study of the bacteria number was carried out using the method of inoculation of solid nutrient media and direct microscopic count. The number of saprotrophic aerobic bacteria was determined on meat-peptone agar. Bacteria, consuming mineral forms of nitrogen, and actinomycetes were cultivated on starch-ammonia agar. The number of oligotrophic bacteria was determined on the low-mineralized Aristovskaya's medium. The total number of bacteria was taken into account by the fluorescence microscopy method using the dark-colored polycarbonate Cyclopore Black membrane filters with 0.2 μm diameter. Preparations were made unde the help of the microscoper of 100x × 10x magnification. Bacteria cells were calculated in 50 viewing field.

Identification of dominating bacteria, recovered from the circulating water was carried out based on the comparative analysis of primary sequences of 16S rRNA genes and a subsequent comparison of nucleotide sequences using the neighbor-joining algorithm at the Analytical Centre of RAS "Biotekhnologia" (Biotechnology), Moscow.

Bacteria Impact on the Process of Apatite-Nepheline Ore Flotation

To study the microorganisms' impact on the flotation process of pure apatite and calcite minerals and apatite from ore, bacteria dominating in the circulating water were used. Experiments were carried out in the open and closed cycle with bacterial suspensions of various densities from 10^2 to 10^7 cells/mL.

Selection of Bactericide Compounds

To develop the methods of reduction of the negative impact of the bacterial component of circulating water, the following oxidizers were used: hydrogen dioxide, potassium permanganate, and sodium hypochlorite (obtained by chemical-electric method). Concentrations of bactericide compounds have made 2.0, 5.0, 7.5 mg/g; the time of their impact—5, 15, 30 min and 24 hours. Control—the variant without of bactericide compounds. The account of the number of surviving cells was taken using the seeding method on meat-peptone agar.

Conditions of experiments in hypochlorite impact on the bacteria number in the process of flotation were as follows: pH of the flotation 9.6–9.8; reagents' consumption: the basic flotation–collective mixture (CM) = 65 g/t, neonol = 15 g/t; recleaner flotation–CM = 25 g/t.

Impact of Microbiological Factor on Mineral Surface Properties Change

Bacteria *Pseudomonas plecoglossicida* were extracted from apatite-nepheline ore. Fungi *Aspergillus niger* was extracted out of Kola Peninsula soil. 3-days bacterial culture was introduced in the Erlenmeyer flasks of volume 250 mL with 50 ml nutrient medium of the following composition: K_2HPO_4 – 0.1 g , $MgSO_4$ – 0.3 g, $CaCl_2$ – 0.2 g, $(NH_4)_2SO_4$ – 1 g, glucose – 10 g per 1 L of distillate water, pH 6.6. Initial density of bacteria was 10^4 cells per 1 mL. The 6-days fungal culture was introduced into flasks with 100 ml Czapek's medium: $NaNO_3$ – 3 g, KH_2PO_4 – 1 g, $MgSO_4$ – 0,5 g, KCl – 0,5 g, $FeSO_4$ – 0.01 g, sucrose – 30 g per L of distillate water, pH 4.1. Nepheline was added into medium of 20g per 100 mL of medium (1:5), cyanite – 5 g per 50 mL of medium (1:5), particle size was 100 microns. The minerals were sterilized separately from nutrient media in the drying oven at 120°C during 3-4 hours. There were two variants: control without introducing of microorganisms and experiment with introducing of bacteria or fungi. In the flasks with medium inoculated with bacteria during the first 3 days they were grown in thermostating shaker, then in thermostat at 27°C during 9 and 37 days. Flasks with fungi were incubated at 27°C. After 12, 20, 30 and 60 days the pH of medium, fungi biomass and content in the solution of Al_2O_3, CaO (atomic absorption method used) and SiO_2, P_2O_5 (colorimetric method used) were determined. Biogenous destruction indexes can also be the changing of infrared spectra of the minerals under study. For that purpose apatite, nepheline and cyanite were exposed to acid-forming bacterium *Pseudomonas plecoglossicida* and alkaline-forming bacterium *Rhodococcus erythropolis* for 12 days. The paper deals with impact of microorganisms on cyanite as it is the lowest soluble among minerals under study.

Results and Discussion

Dynamics of Bacteria Number in Circulating Water

Microorganisms got in the benefication process from circulating water and partly with the ore, going to the processing. It has been found that the number of saprotrophic bacteria in the circulating water varied from 0.3 thousand cells/mL to 420 thousand cells/mL during a year, reaching the largest indices in the spring-summer period, while the minimum number was found in December–February (Fig. 1). The average number of saprotrophs in the circulating water made 109.0 ± 21 thousand cells/mL.

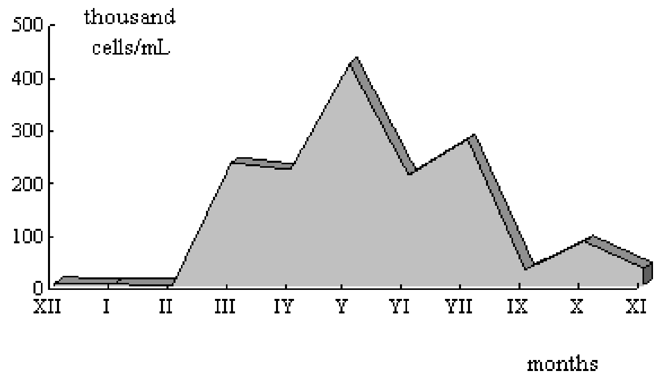


FIG. 1 THE AMOUNT OF SAPROTROPHIC BACTERIA IN THE CIRCULATING WATER OF THE APATITE-NEPHELINE CONCENTRATING MILLS (THOUSAND CELLS/ML)

The number of bacteria in circulating water, as well as in the natural one, depends on variations of the water temperature, pH values and the content of nutrient elements in them. The pH values of circulating water varied during the year within the range of 8.4–9.3. The temperature of circulating water, getting to the concentration process, varied depending on the season from +2 to +16°C and was the highest in June–August. One of the factors, influencing the number of microorganisms in circulating water, is the ion composition of water. Mineralization index of the circulating water, coming to the concentrating mill, made on the average 780 ± 12 mg/L and remained relatively uniform during the year.

Using the fluorescence microscopy method the total number of bacterial cells varied during the year from 8 to 29 million cells/mL (Fig. 2). The average values of the total number of bacteria in circulating water have made 17.7±1.8 million cells/mL, their biomass – $(7.2\pm0.7)\times10^{-4}$ mg/mL. It should be noted that both living and unviable cells are taken into account by the microscopy method. However, dead cells as well as the living ones are characterized by high sorption properties and are capable of influencing the process of interaction between bacteria and the minerals' surface. The total number of bacteria in the circulating water, as well as their saprotrophic component, is subject to seasonal changes. Their number increases from the winter-spring period to the spring-summer one.

The Number of Microorganisms in a Cycle of Apatite-Nepheline Ore Benefication

The number of microorganisms has been noted during the flotation of apatite-nepheline ores. Especially considerably it increases in the froth product, which is connected with the improvement of conditions of their habitat due to the pulp aeration and additional introduction of organic substances –sources of energy and carbon. The content of water-soluble carbon in the circulating water made 15.6 ± 2.0, in the froth product—36.6±4.0 mg/L. Right here, the maximum number of saprotrophic bacteria was found (Table 1). Coefficient of correlation of the number of saprotrophic bacteria with the content of the water-soluble carbon in the technological process samples made 0.9.

TABLE 1 THE NUMBER OF BACTERIA (THOUSAND CELLS/ML OR CELLS/G) DURING THE PROCESSING OF APATITE-NEPHELINE ORES, M ± m (MEAN AND ERROR OF MEAN)

Sample	**Saprotrophs**	**Using the mineral nitrogen**	**Oligotrophs**
Ground ore	80 ± 35	35 ± 8	41 ± 7
Mill overflow	20 ± 7	4 ± 2	5 ± 2
Froth product	5754 ± 957	4044 ± 765	185 ± 55
Flotation tailings	4781 ± 743	1140 ± 87	206 ± 23
Thickeners' overflow	990 ± 86	499 ± 33	295 ± 64
Filtrate	2491 ± 56	1349 ± 485	693 ± 94
Neonol	0	1 ± 0.1	5 ± 1
Collective mixture	0	0	0
Circulating water	109 ± 21	448 ± 54	19 ± 7

The number of bacteria using mineral nitrogen is higher, compared to saprotrophic ones using organic compounds' nitrogen. A high number of microorganisms is still found in flotation tailings and the filtrate. No growth of microorganisms in the filtrate has been found after drying and collective mixture, which is explained by the high temperature of

drying and high pH values of the collective mixture (pH–10.5).

Biodiversity of Bacteria, Dominating in Circulating Water of a Concentration Mill

All dominating bacteria strains with the frequency of occurrence over 60% were isolated into pure cultures. According to the results of comparative studies of sequences of genes' 16S rRNA, they refer to *γ-Proteobacteria* and identified as *Pseudomonas plecoglossicida* FPC951^T, *Stenotrophomonas rhizophila* e-p10^T and *Acinetobacter sp.*

Bacteria Impact on Flotation of pure Differences of Apatite and Calcite

As a result of experiments in flotation of pure differences of apatite and calcite minerals, as calcium-bearing minerals, when adding in the process bacterial suspension of different density, a conclusion was drawn (Fig.2) that every tested bacteria species play a negative role in the flotation of both apatite and calcite [4].

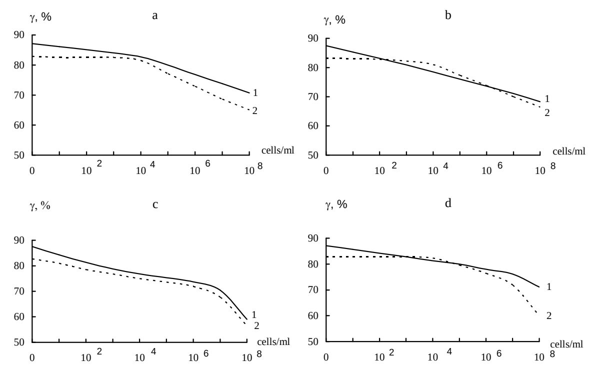


FIG. 2 RELATIONSHIP BETWEEN APATITE (1) AND CALCITE (2) FLOTABILITY AND BACTERIA NUMBER (CELLS/ML) AT CONSTANT PH - 9.8 AND SODIUM OLEATE - 10 MG/L

γ - froth product yield (%); a – *Acinetobacter sp.*; b - *Pseudomonas alcaliphila*; c - *Stenotrophomonas rhizophila*; d – *Pseudomonas plecoglossicida*.

The bacteria strains dominating in circulating waters can be placed in a row, according to the degree of their negative impact on the floatability of minerals: *Stenotrophomonas rhizophila* > *Pseudomonas plecoglossicida* > *Acinetobacter sp.* = *Pseudomonas alcaliphila.* With introduction in flotation of bacteria *Stenotrophomonas rhizophila* the deterioration of apatite and calcite floatability reached 30%.

Bacteria Impact on Flotation of Apatite from Ore

Having experiments, based on pure differences of minerals gave rise to passing on to flotation tests, based on base ores, processed at the mill. Data in Table 2 testify to the negative impact of bacteria on apatite flotation from ore. It is especially clearly manifested in a closed-loop cycle flotation, which is characteristic for the process of flotation, carried out at the mill. In a closed-loop cycle, at the circulation of middlings, the selectivity of process is broken, which is confirmed by the increase of the product yield with the same recovery due to the deterioration of the concentrate quality, compared to experiments, carried out in laboratory conditions without bacteria. Consortium of bacteria *Stenotrophomonas rhizophila, Pseudomonas alcaliphila* and *Pseudomonas plecoglossicida* exerts a strong negative influence. They reduce the content of P_2O_5 in the concentrate by 3% (Table 2).

TABLE 2 RESULTS OF FLOTATION FROM ORE IN PRESENCE OF BACTERIA (*STENOTROPHOMONAS RHIZOPHILA, PSEUDOMONAS ALCALIPHILA* AND *PSEUDOMONAS PLECOGLOSSICIDA*) IN A CLOSED-LOOP CYCLE (%)

Product	Yield	P_2O_5 content	P_2O_5 recovery	Number of bacteria, cells/mL
Concentrate	36,3	40,42	94,6	0
The same	36,3	39,50	95,3	10^2
- " -	38,3	38,12	95,1	10^3
- " -	39,0	37,45	95,0	10^6

The deterioration of floatability of the studied minerals can be explained both by bacteria interaction with their active centres, connected by calcium, and by intense flocculation during the flotation, breaking the selectivity of the process. Having a negative charge of cells' surface, bacteria block the centres, connected with calcium, weaken its role played in the flotation process as a connecting link between the surface of mineral and surface-active agents—anion collectors. Number of bacteria in the circulating water depending on the season of the year can reach n×10^6-n×10^7 cell/mL, which in the technological process deteriorates the floatability of minerals. Coagulation that affects the selectivity of flotation process, starts when the number of bacteria is exceeded up to n×10^5 – n×10^6 cell/mL.

Development of Methods of Bacteria Impact Elimination on Flotation Processes

There were tested strong oxidizers as bactericide compounds: hydrogen dioxide, sodium hypochlorite and potassium permanganate. Currently sodium hypochlorite (NaClO) is broadly used for water decontamination.

Experiments on the bactericide compounds impact on vital activity of bacteria have shown that sodium hypochlorite is the most efficient as bactericidal agent. The share of surviving cells of all bacteria species under the impact of the studied concentrations of sodium hypochlorite (2, 5, 7.5 mg/L) during 5 min did not exceed 2%. At the concentration of NaOCl 10 mg/L all cells died.

Influence of Sodium Hypochlorite on Bacteria in the Process of Flotation

In the 1st experiment (control), flotation was performed on circulating water without NaClO with usual consumption of the collecting mixture - 65 g/t in the basic flotation and 25 g/t in control flotation (Table 3). In the 2 experiment, NaClO, inhibiting the vital functions of bacteria, was introduced into basic the flotation, while keeping the same collecting mixture consumption rate. At that, the same kind of recovery was observed as in the control test, the concentrate yield grew; however, it proved to be substandard in quality (the content of P_2O_5 < 39%), which testified of the excess of collecting mixture and disturbance of the selectivity of the process. Therefore, in the next test (experiment 3) we reduced the collecting mixture consumption and acquired the same indices in recovery and content of P_2O_5, as in the control test. In test 4 flotation was performed on circulating water without hypochlorite with the same amount of collecting mixture as in test 3, i.e., with reduced content of it. At that, the recovery of P_2O_5 dropped by 4%, which testifies of the insufficient amount of collecting mixture.

Thus, the results of experiments on the reducing of negative bacteria impact on the flotation process testify to that the most efficient bactericide compound for these purposes is sodium hypochlorite that practically completely sterilizes the bacterial suspension during 5 min with concentration 2–5 mg/L. This concentration of sodium hypochlorite does not reduce the efficiency of the flotation process. The reduction of bacteria number in the circulating water will allow to reduce collectors' consumption at the flotation of apatite-nepheline ore on 15–20%.

Impact of Microbiological Factor on Surface Properties of Minerals in Composition of Tailing Wastes

If one takes into account importance of bacteria during flotation recovery of minerals, it is necessary to expect that they interact with solid phase of tailings as well. Both direct and indirect mechanisms are known to

TABLE 3 FLOTATION OF APATITE FROM ORE IN CIRCULATING WATER IN PRESENCE OF SODIUM HYPOCHLORITE

№ of experiment	Product	Technological indices, %			Note
		Yield	P_2O_5 content	P_2O_5 recovery	
1	Concentrate	32.70	39.78	95.10	Circulating water without NaClO
	Tailings	67.30	1.01	4.90	Consumption of CM:
					basic fl. – 65 g/t control fl. – 25 g/t
	Ore	100.00	13.73	100.00	
2	Concentrate	33.50	38.91	95.50	NaClO in basic fl. = 2 mg /L
	Tailings	66.50	0.93	4.50	Consumption of CM is the same
	Ore	100.00	13.65	100.00	
3	Concentrate	32.80	39.72	95.00	NaClO in basic fl. = 2 mg /L
	Tailings	67.20	1.04	5.00	Consumption of CM:
	Ore	100.00	13.73	100.00	basic fl. – 55 g/t control. fl. – 20 g/t
4	Concentrate	31.4	39.49	91.2	Circulating water
	Tailings	68.6	1.74	8.8	Consumption of CM:
	Ore	100.0	13.59	100.0	basic fl. – 55 g/t control fl. – 20 g/t

CM – collective mixture; basic fl. – basic flotation; control fl. – control flotation.

impact on minerals [2, 3]. Direct microorganisms impact on minerals takes place when microbial cells are in direct contact with mineral particles. There are two main types of the direct impact: destruction under impact of enzymes and microbial polysaccharidic mucus that promote cell adherence to the mineral surface. Carboxylic and phenol groups in its composition destroy the mineral crystalline grids.

The most efficient mineral biogenous destruction occurs under indirect impact of microorganisms on minerals by metabolic products that represent strong chemical agents. They include mineral acids (nitric acid and sulphuric acid), produced by autotroph nitrifying bacteria and sulphur bacteria, organic acids (citric acid, acetic acid, formic acid, oxalic acid, amber acid, tartaric acid and other) produced by the whole series of heterotrophic bacteria and microscopic fungi.

Fungi are characteristic of acid formation. It is assumed that citric acid formation is the most frequent biochemical process with fungi [6]. It is this acid that promotes for fast destruction of alumosilicates [7]. The fungi *Aspergillus niger* we obtained, decreased the pH value by 2 units (from 4 to 2) in 7 days in the experiment of heavy metal accumulation by mycelium [5]. The intensive release of Si from alumosilicates under the impact of *Penicillium notatum* fungi acid metabolite is shown [1].

We studied the impact of *Asp. niger* fungus on cyanite as the lowest soluble mineral among minerals under study. Addition of apatite-nepheline flotation tailings into medium promotes *Asp. niger* growth. In the variant with tailings, the fungi biomass, sporation is higher and more active than in control variant that can be proved by the data in the Table 4. Fungi biomass in the experiment variant was 2 times higher than in control one. It can be explained by biogenous elements transition–growth stimulator from tailings into solution with acid reaction.

The initial value of pH was 4.1. Already after 12 days in the control variant there was significant decrease of pH due to active synthesis of citric acid by fungi that we discussed earlier [5]. pH values till the end of experiment in the control were 2.0. In the variant with introduction of tailings that was able to perform alkaline reaction, pH during the two weeks was still within the acid range (pH 5.6). However, within the

TABLE 4 BIOMASS *ASPERGILLUS NIGER* AND PH OF MEDIUM IN THE EXPERIMENT WITH APATITE-NEPHELINE FLOTATION TAILINGS

Days	Biomass, g		pH	
	control	experiment	control	experiment
0	-	-	4.09	5.68
12	0.38	0.94	1.98	5.66
20	0.47	0.81	2.15	8.91
30	0.49	0.75	2.10	8.97
60	0.44	0.73	2.28	9.20

Note. Control variant – medium with *Aspergillus niger,* without tailings; experiment - medium with *Aspergillus niger* and with of tailings.

TABLE 5 DYNAMICS OF MACROELEMENTS CONTENT (MG/L) IN THE SOLUTION OF *ASPERGILLUS NIGER* IN THE EXPERIMENT WITH APATITE-NEPHELINE FLOTATION TAILINGS

Days	SiO_2		Al_2O_3		P_2O_5		CaO	
	control	experiment	control	experiment	control	experiment	control	experiment
12	2.7	430.0	0.6	766.0	-	-	1.3	0.1
20	1.5	560.0	0.8	130.0	168.0	145.0	1.9	6.8
30	9.9	15.5	0.5	10.9	460.3	83.0	1.0	6.5
60	traces	78.5	0.9	9.7	387.2	116.0	0.3	4.9

Note. Control variant –with flotation tailings, without *Aspergillus niger*; experiment – with flotation tailings and with *Aspergillus niger.*

interval of 12-20 days intense alkalinization occured in the medium – for more than 3 units. It can be connected with significant leaching of Si and Al and large amounts of alkaline and alkaline-earth metals from tailings during this period (Table 5).

By analyzing obtained data it can be seen that content of biogenous Al and Si is determined by acid-base regime of the medium: the more acid the medium, the faster comes the nepheline destruction. In the acid medium the amount of SiO_2 and Al_2O_3 is ten times higher rather than in the alkaline medium. One month after experimenting, SiO_2 and Al_2O_3 content in the solution significantly decreased that can be explained by retardation of the biogenous mineral destruction and transition of elements in the solution into sedimentation due to medium alkalinization. It should be noted that the degree of the earth silicon leaching from the flasks' glass (where research fungi was grown) is negligible (1.5 mg/L) compared to intensity of biogenous solving of the nepheline earth silicon.

P and Ca are biogenous elements that are necessary for fungi growth and their biochemical processes. That's why there is no wonder that these elements are less where the active mycelium growth is, i.e. when adding flotation tailings in the medium.

Considered macroelements leaching from nepheline-containing wastes by *Aspergillus niger* was indirect using organic acids produced by it. Fungus film was developed on the liquid medium surface and didn't contact directly with particles of the flotation tailings.

Bacteria *Pseudomonas plecoglossicida* used in the experiment with cyanite were as well active acidifiers, reducing pH of the nutritional medium from 6.6 to 3.6 during first 12 days. In the acid medium the cyanite destruction took place. Amount of Al_2O_3 increased during 12 days with bacteria in 16 times compared to control variant without bacteria, amount of SiO_2 – in 7 times (Table 6). In 40 days this difference increased up to 23 and 10 times respectively.

TABLE 6 CONTENT OF SILICON AND ALUMINIUM OXIDES (MG/L) IN THE SOLUTION WITH *PSEUDOMONAS PLECOGLOSSICIDA* IN THE EXPERIMENT WITH CYANITE

Days	SiO_2		Al_2O_3	
	control	experiment	control	experiment
12	20.4	152.2	18.4	293.0
40	21.8	226.7	20.1	468.2

Under the impact of bacteria, the surface properties of the minerals are changing as a result of the sparingly soluble complex compounds formation between organic acids and crystalline grid cations. As infrared spectrum of cyanite showed, the most significant changes are found under the impact of acid-forming bacteria *Pseudomonas plecoglossicida* during 12 days in comparison with spectrum of initial cyanite (Fig.2). The infrared spectrum of cyanite directly indicates the general amorphization of the cyanite crystalline structure in the acid medium that is determined by bacteria *Pseudomonas plecoglossicida* life activity. In the alkaline medium, under the impact of *Rhodococcus erythopolis*, no significant changes in absorption bands are found in comparison with initial cyanite spectrum.

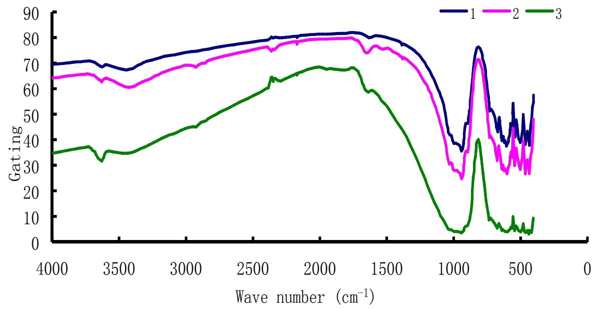
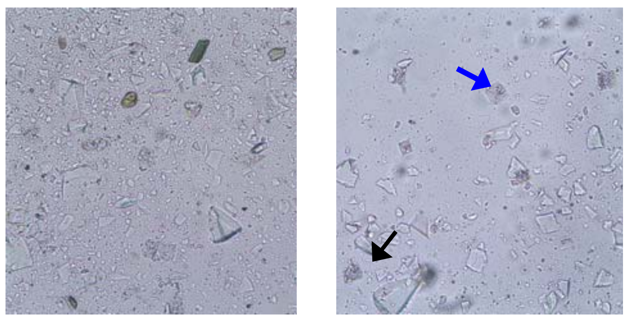


FIG. 3 INFRARED CYANITE SPECTRUM

1 – initial cyanite; 2 – cyanite after impact of alkaline-forming bacteria *Rhodococcus erythopolis*, 12 days; 3 – cyanite after impact of acid-forming bacteria *Pseudomonas plecoglossicida*, 12 days.

In apatite spectrum during 12 days to the *Asp.niger* metabolites' impact, strong absorption bands of 1618 and 1317 cm^{-1} were found, which are referred to crystals of calcium oxalate (Fig.4) based on the crystal optics and X-ray phase analysis.



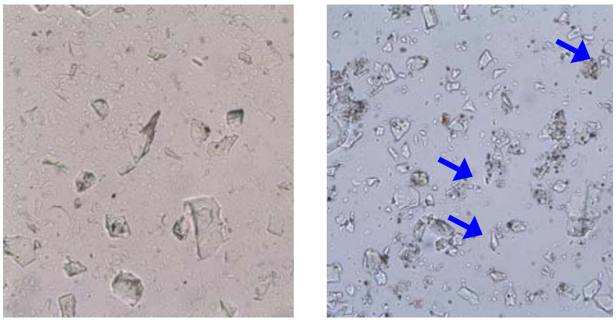
Apatite initial Apatite after *Aspergillus niger* impact

FIG. 4 IMPACT OF *ASPERGILLUS NIGER* ON APATITE

- calcium oxalate as crystals

- calcium oxalate amorphized

In nepheline exposed to *Asp.niger* impact during 12 days, the new phase was found under the microscope as dark balls that seem to be aluminium oxalate. However, X-ray phase analysis didn't confirm the assumption, probably, due to its x-ray amorphism (Fig.5).



Nepheline initial   Nepheline after *Aspergillus niger* impact

FIG. 5 IMPACT OF *ASPERGILLUS NIGER* ON NEPHELINE

- aluminium oxalate.

Conclusions

As a result of carried out investigation, it was revealed that apatite-nepheline ore flotation favour bacteria reproduction. The maximum number of bacteria is reached in the froth product, which is, first of all, connected with the increase of the pulp temperature, its additional aeration and ingress of organic substances with flotoreagents. In the circulating water bacteria *Pseudomonas, Stenotrophomonas, Acinetobacter* genera dominate. Bacteria *Stenotrophomonas rhizophila* have the largest impact on flotation of apatite and calcite. The deterioration of floatability of minerals reached 30%. The reason of it is the interaction of bacteria with active centres, connected with calcium-containing minerals and intense flocculation, breaking the selectivity of the process. With a negative charge of cell's surface, they block the centres connected with calcium. Bacteria exert a negative impact on the apatite flotation from ore, beginning with their number of 10^5-10^6cells/mL.

Of all the studied bactericide compounds, sodium hypochlorite inhibits the most efficiently the bacteria development in the flotation process. It practically completely sterilizes the bacterial suspension during 5 minutes at the concentration of 2–5 mg/L, promoting the reduction of the collective mixture consumption.

Microbiological processes are equally important for storage of concentration wastes of apatite-nepheline ores and tailing dumps, which are, in fact, mining-induced deposits. Bacteria, producing acids and polysaccharidic mucuses in the environment, perform biogenic destruction of minerals, accelerating many times hypergenic processes that take place in tailing dumps.

According to our view, one of the basic factors having impact on complex benefication of ore processing wastes is the processes of mineral surface transformation affected by the action of microorgamisms' metabolites.

ACKNOWLEDGEMENT

This work was supported by Programs "Biodiversity" of the Presidium of the Russian Academy of Sciences and Geosciences Department of RAS "Nanosized particles in nature and technogenic products: occurrence conditions, physical and chemical properties and formation mechanisms". Project: "Microbiological factor in the processes of mineral formation and destruction" and JSC "Apatit".

REFERENCES

Aristovskaya, T. V., and Kutuzova, R. S. "On microbiological factors of silicon mobilization out of low soluble natural compounds," Soil Science, vol. 12, pp. 59-66, 1968 (in Russian).

Ehrlich, H. L. "How microbes influence mineral growth and dissolution," Chemical Geology, vol. 132, pp. 5-9, 1996.

Ehrlich, H. L. Geomicrobiology, p. 768 (Marcel Dekker Inc. New York. Basel), 2002.

Evdokimova, G. A., Gershenkop, A. Sh., and Voronina, N. V., "Microbiological processes in the system of mining and processing of apatite-nepheline ores based on circulating water," – Saint – Petersburg: Nauka, p. 102, 2008.

Evdokimova, G. A. and Mozgova, N. P. "Copper and nickel accumulation by soil fungi," J. Microbiology, vol. 60, N 5, pp. 801-807, 1991 (in Russian).

Henderson, M. E. K., and Duff, R. B. "The release of metallic and silicate ions from minerals, rock and soil by fungal activity," J. Soil Sci, vol. 14, N 2, pp. 56-62, 1963.

Ponomareva, V. V., and Ragim-Zade, A. I. "Comparative study of fulvoacids and humic acids as agents of silicate material decomposition, Soil Science," vol. 3, pp. 26-36, 1969 (in Russian and in English).